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(54) **TAPE DRIVE WITH HEAD-GIMBAL ASSEMBLY AND CONTACT PLATE**

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G11B 5/56 (2006.01)
G11B 15/32 (2006.01)

(Continued)

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CPC ***G11B 5/56*** (2013.01); ***G11B 5/00813*** (2013.01); ***G11B 5/581*** (2013.01); ***G11B 5/60*** (2013.01); ***G11B 15/32*** (2013.01); *G11B 15/43* (2013.01)

(58) **Field of Classification Search**
None
See application file for complete search history.

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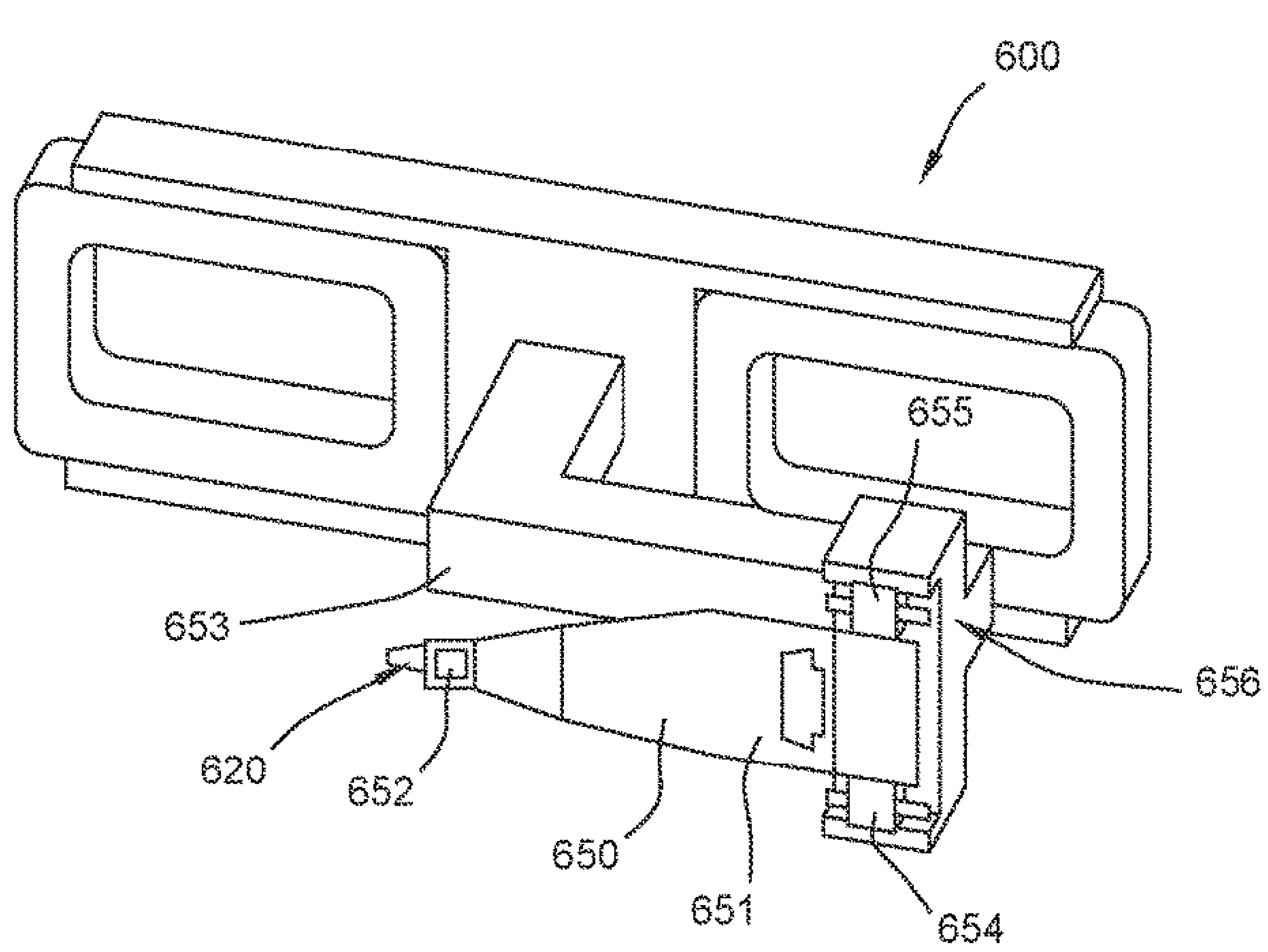
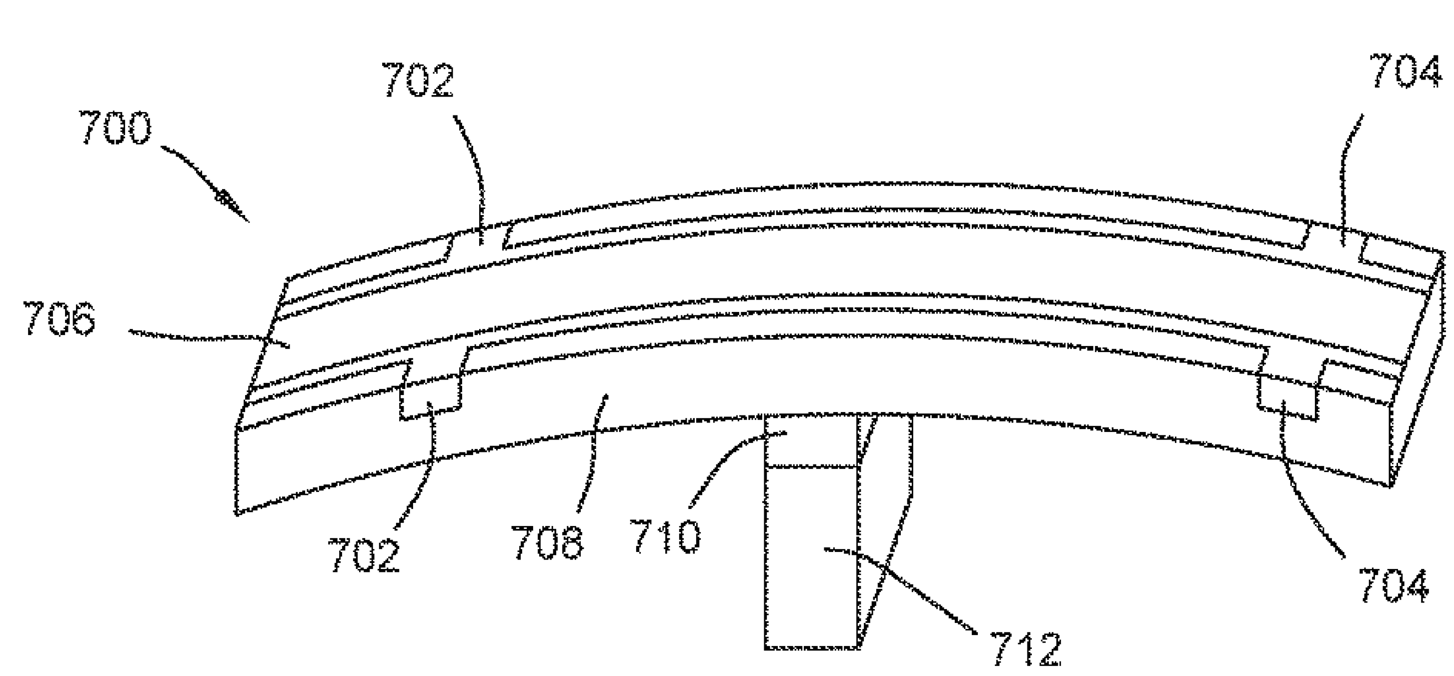
(57) **ABSTRACT**

The present disclosure generally relates to a tape embedded drive having a head-gimbal assembly (HGA) and a contact plate. By using a support structure or contact plate beneath the tape, read and write heads can be designed to be narrower than the tape. The support structure or contact plate can stretch or relax the tape so that the spacing between servo tracks on the tape corresponds to the servo to servo spacing on the head. HGAs, which are narrower than the tape, can fly over the tape and read data from and write data to the tape. The HGA can have a single head or multiple heads. Additionally, multiple independent head assemblies can also be used for reading from and writing to the same tape.

20 Claims, 8 Drawing Sheets





Related U.S. Application Data

continuation of application No. 16/864,050, filed on Apr. 30, 2020, now Pat. No. 11,087,786.

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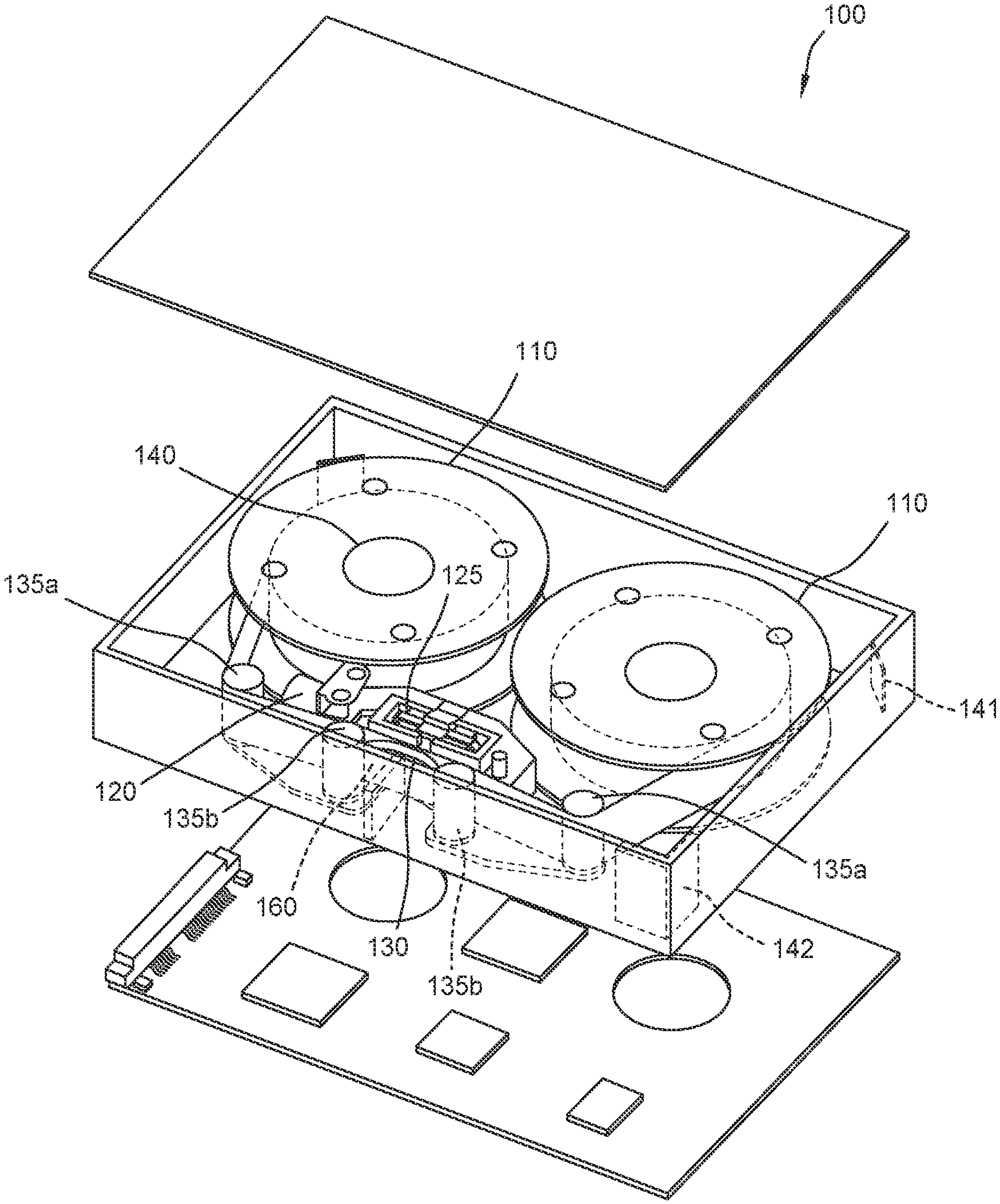

FIG. 1A

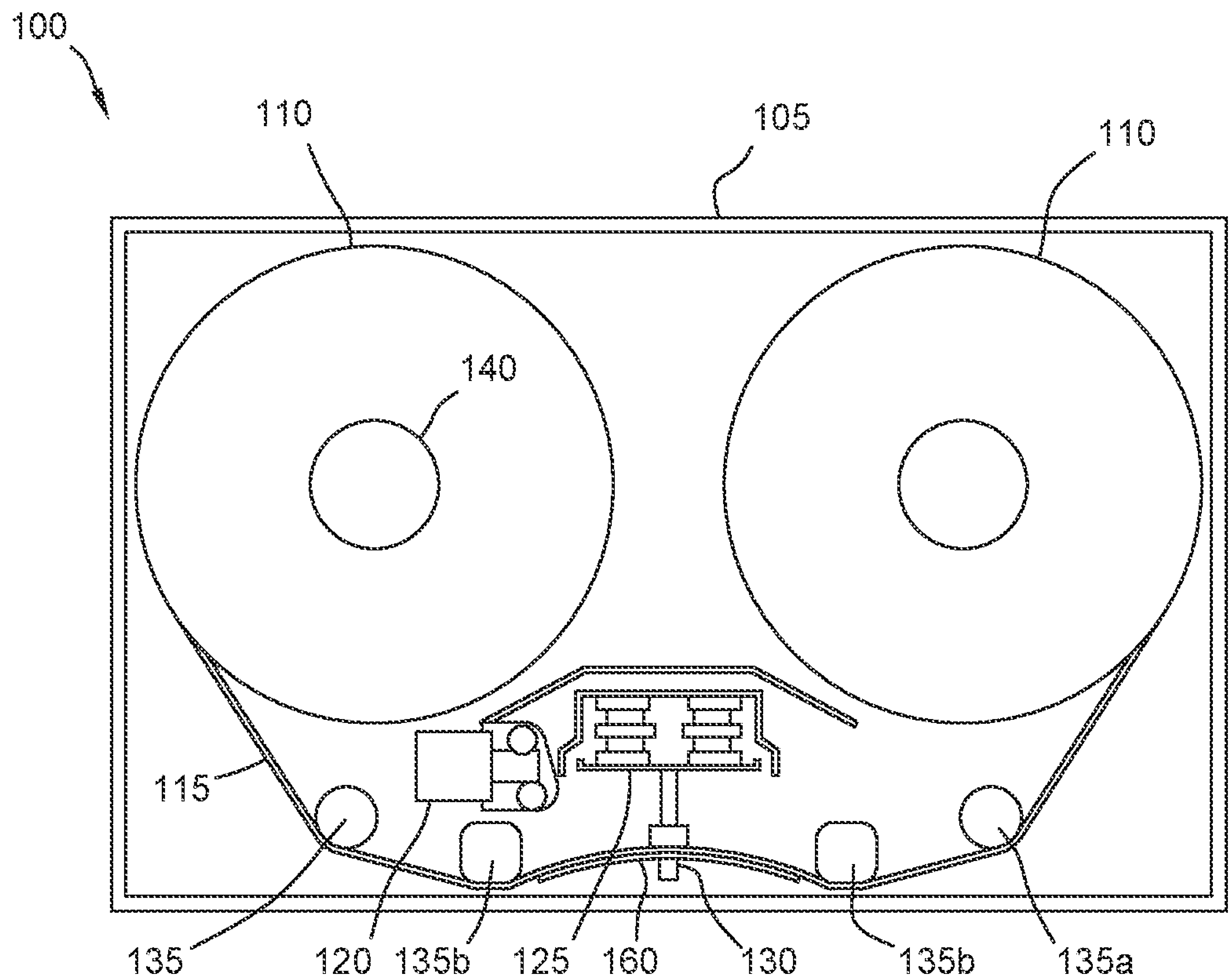
100
110
105
110
140
115
135
120
135b
125
160
130
135b
135a

FIG. 1B

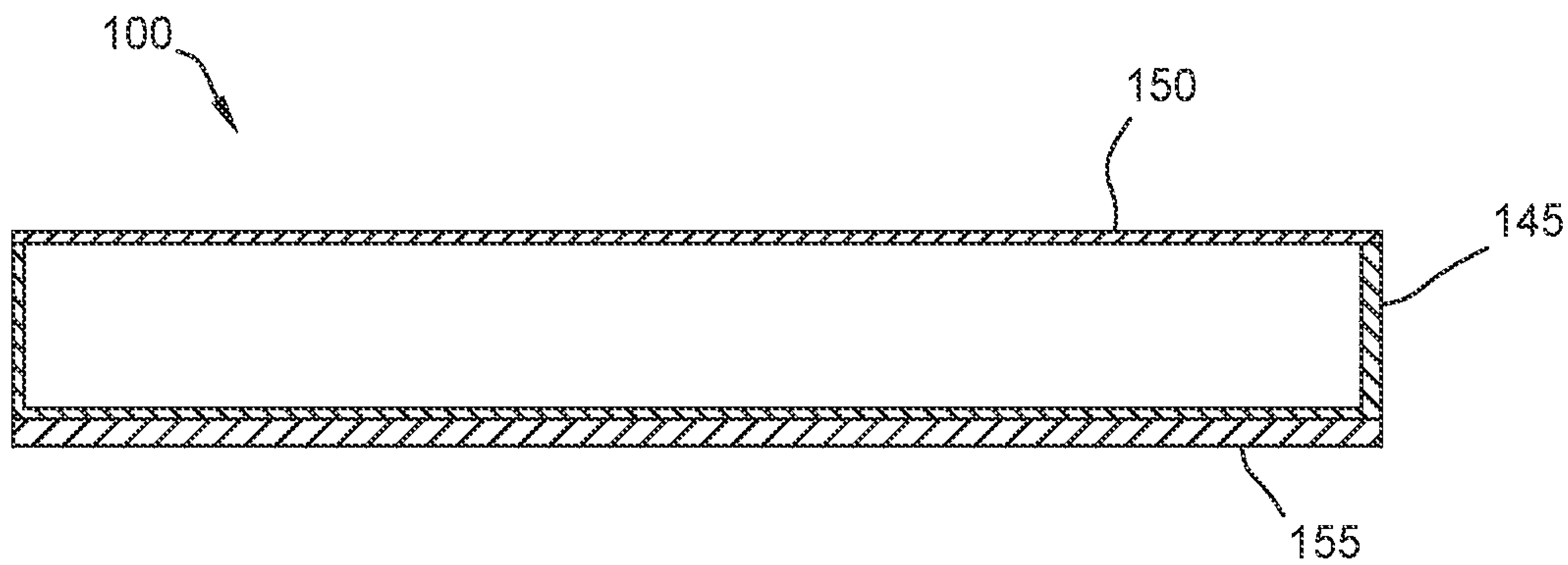
100
150
145
155

FIG. 1C

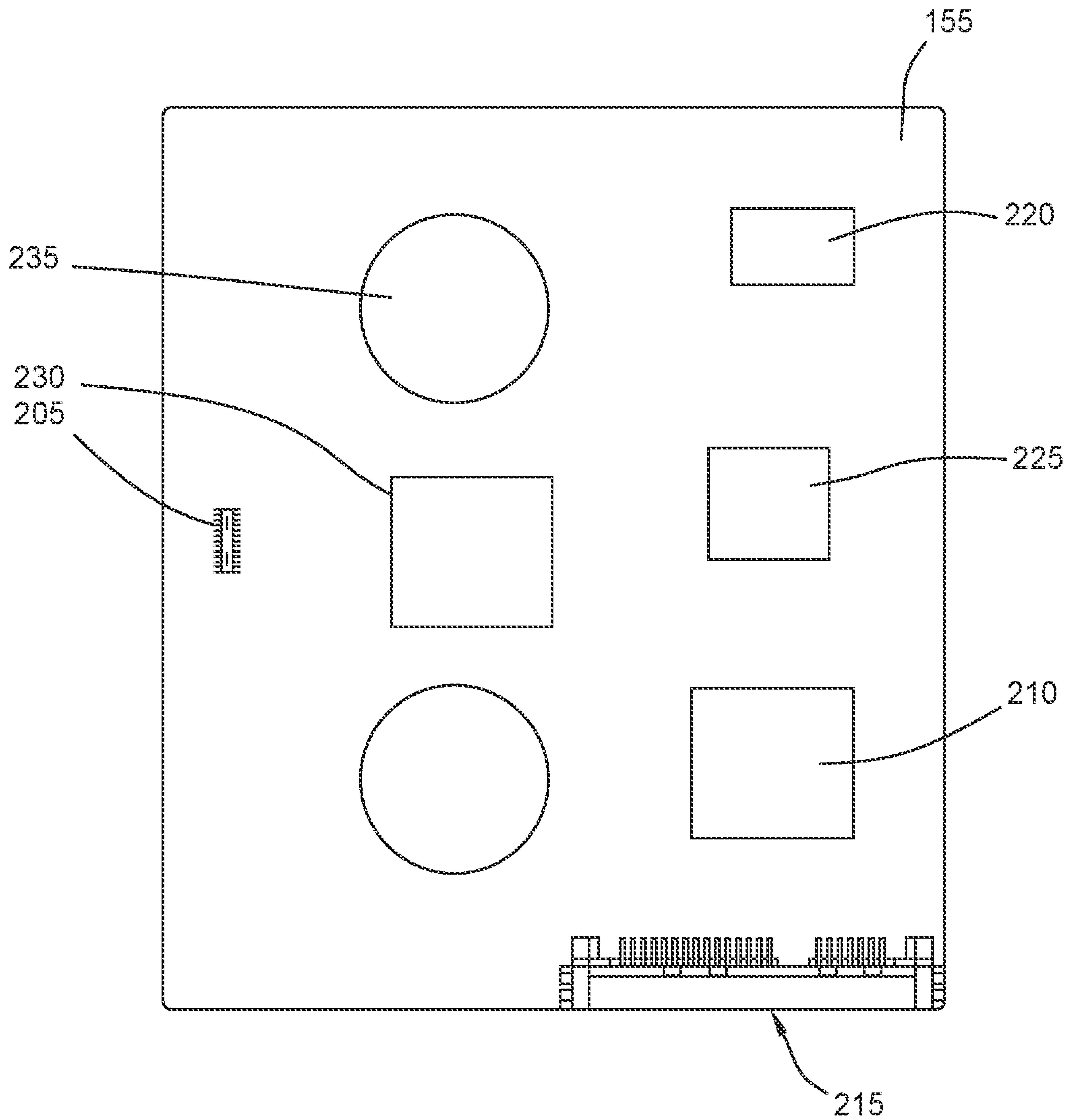

FIG. 2

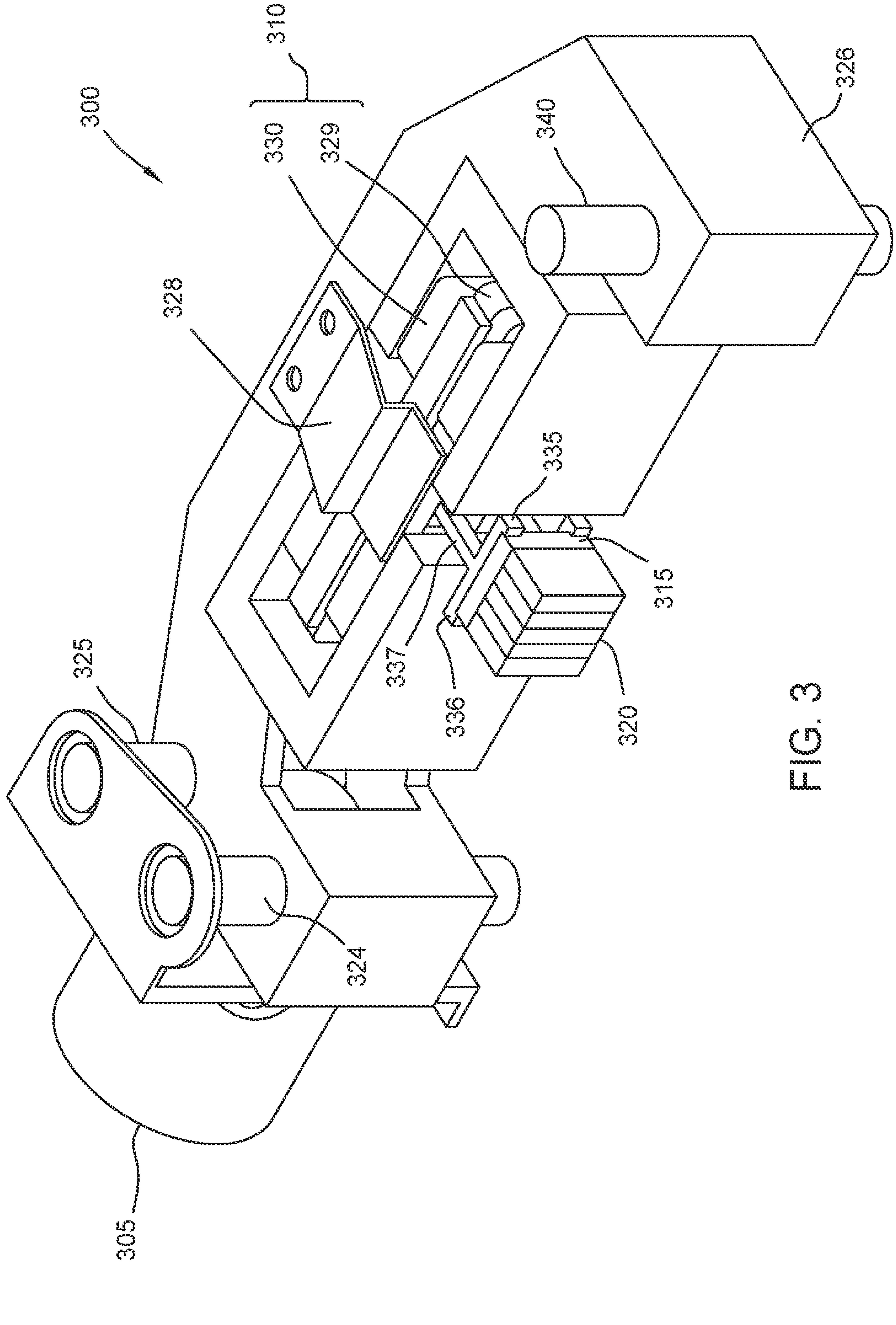

FIG. 3

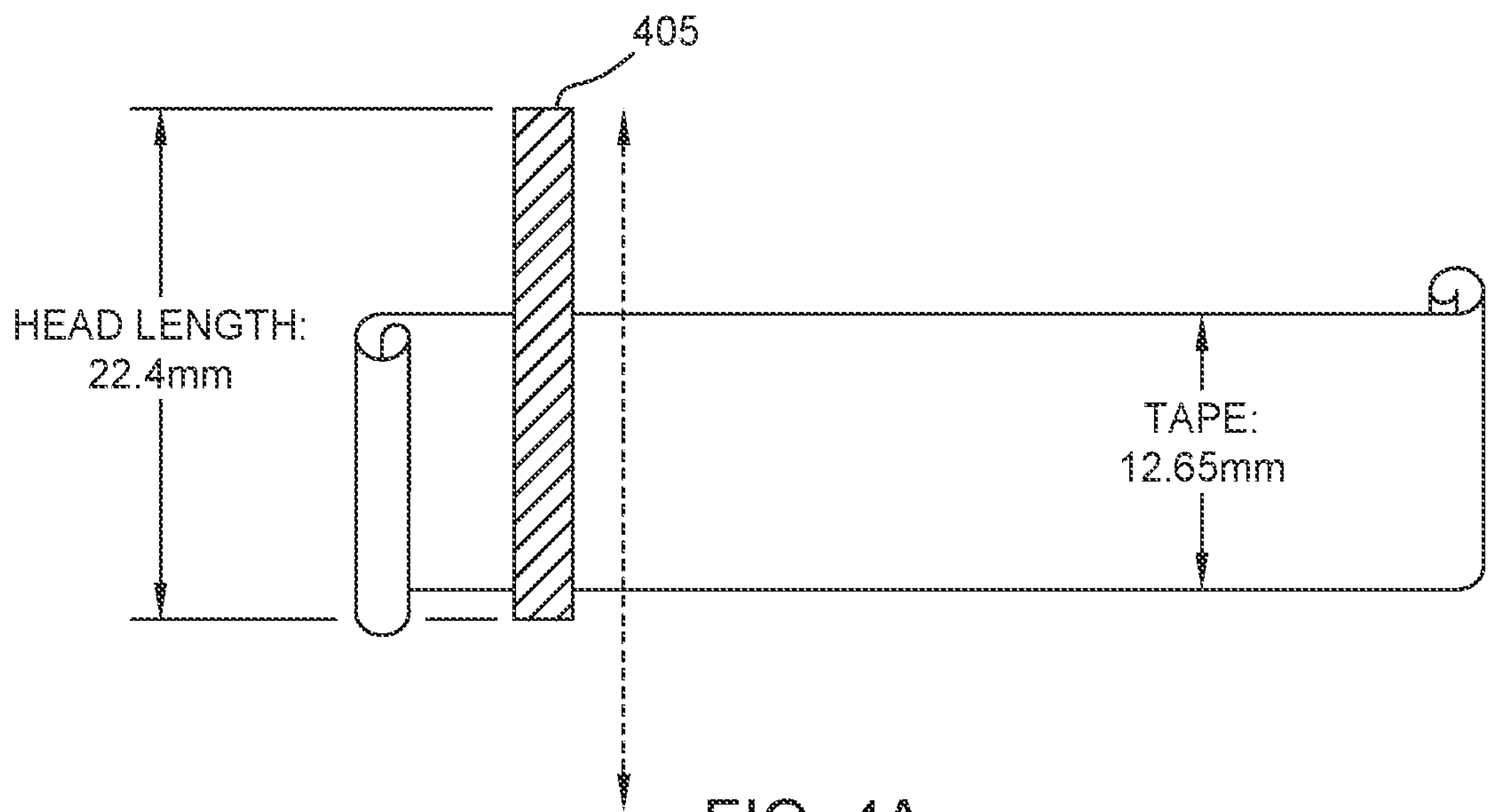

FIG. 4A

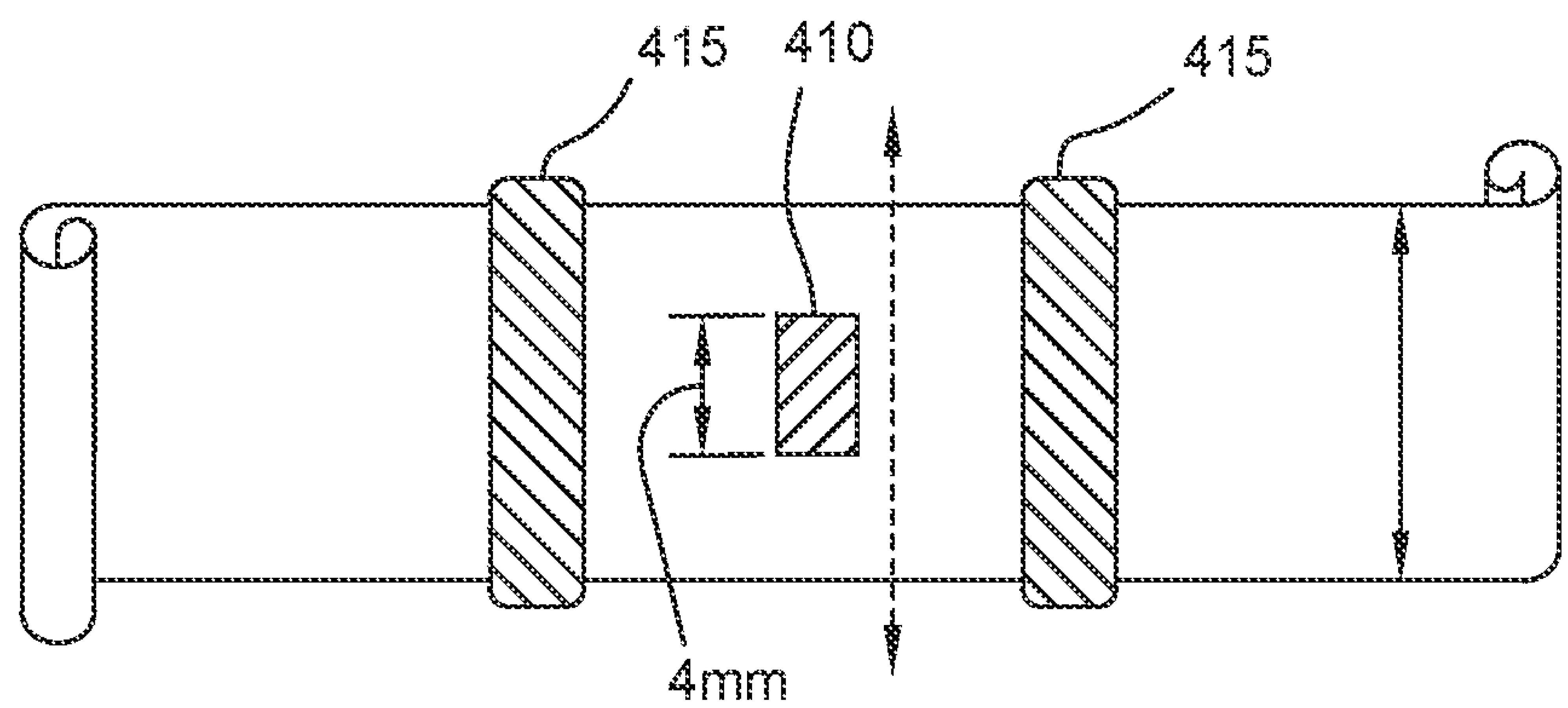

FIG. 4B

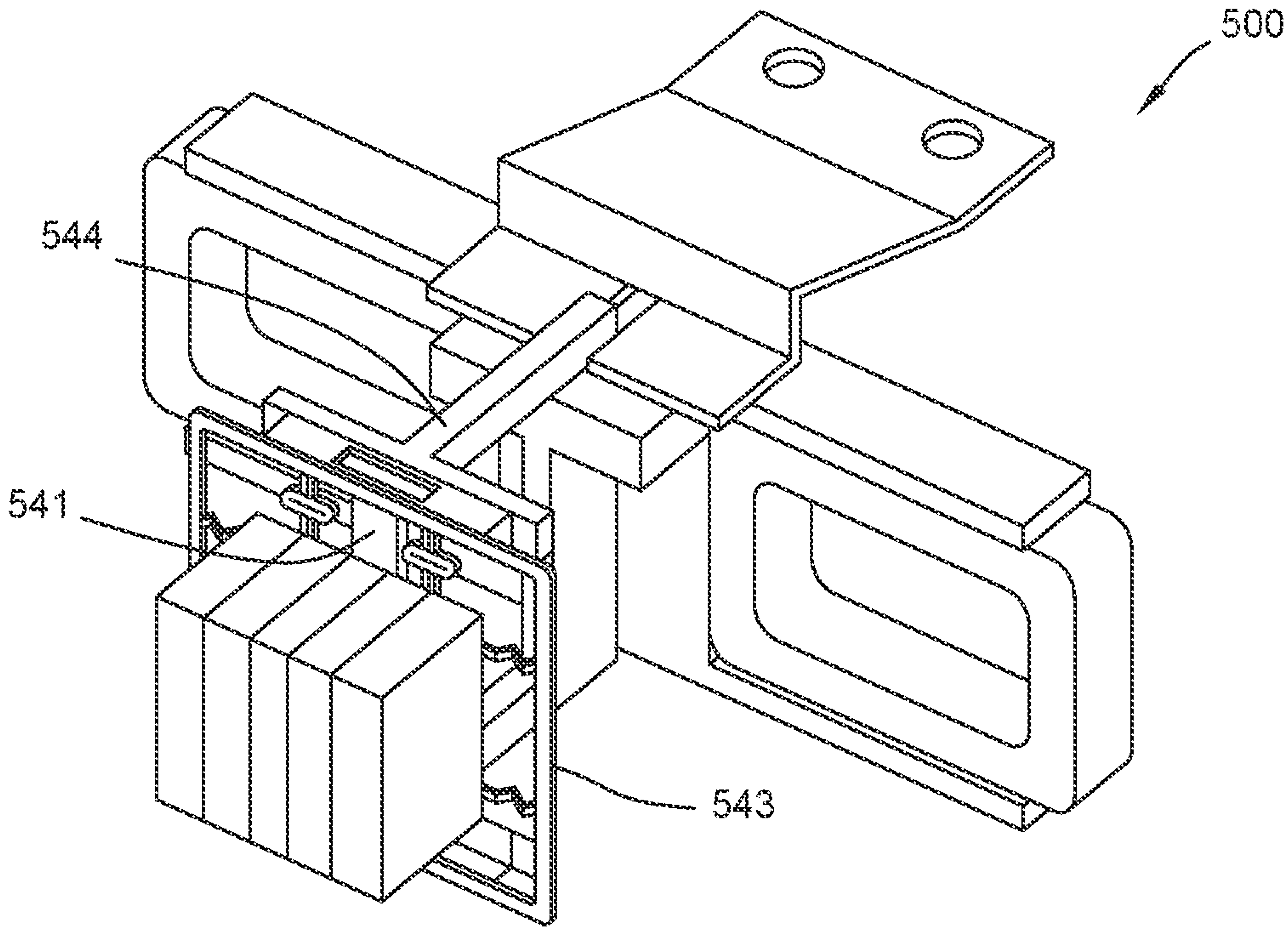

FIG. 5A

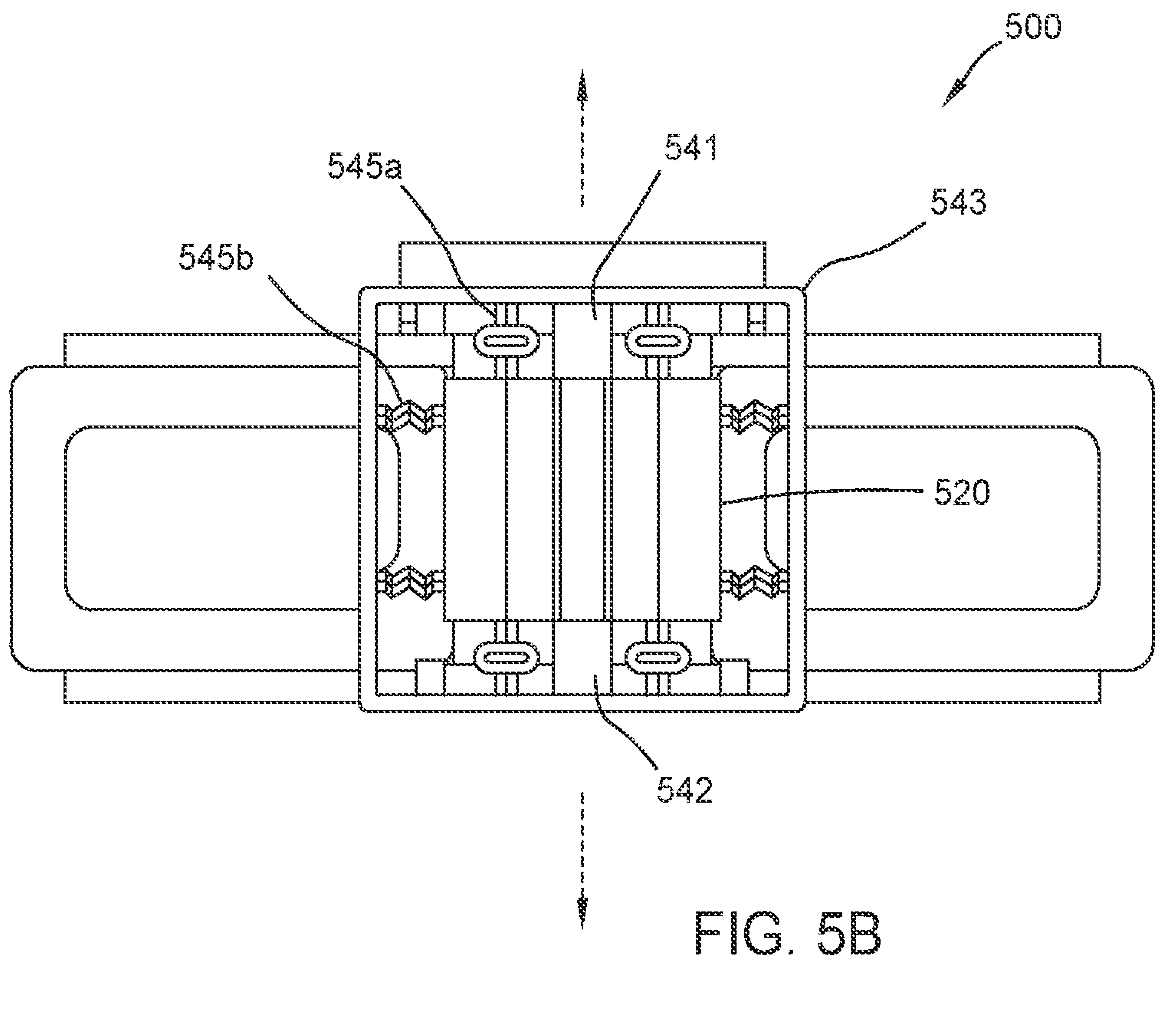

FIG. 5B

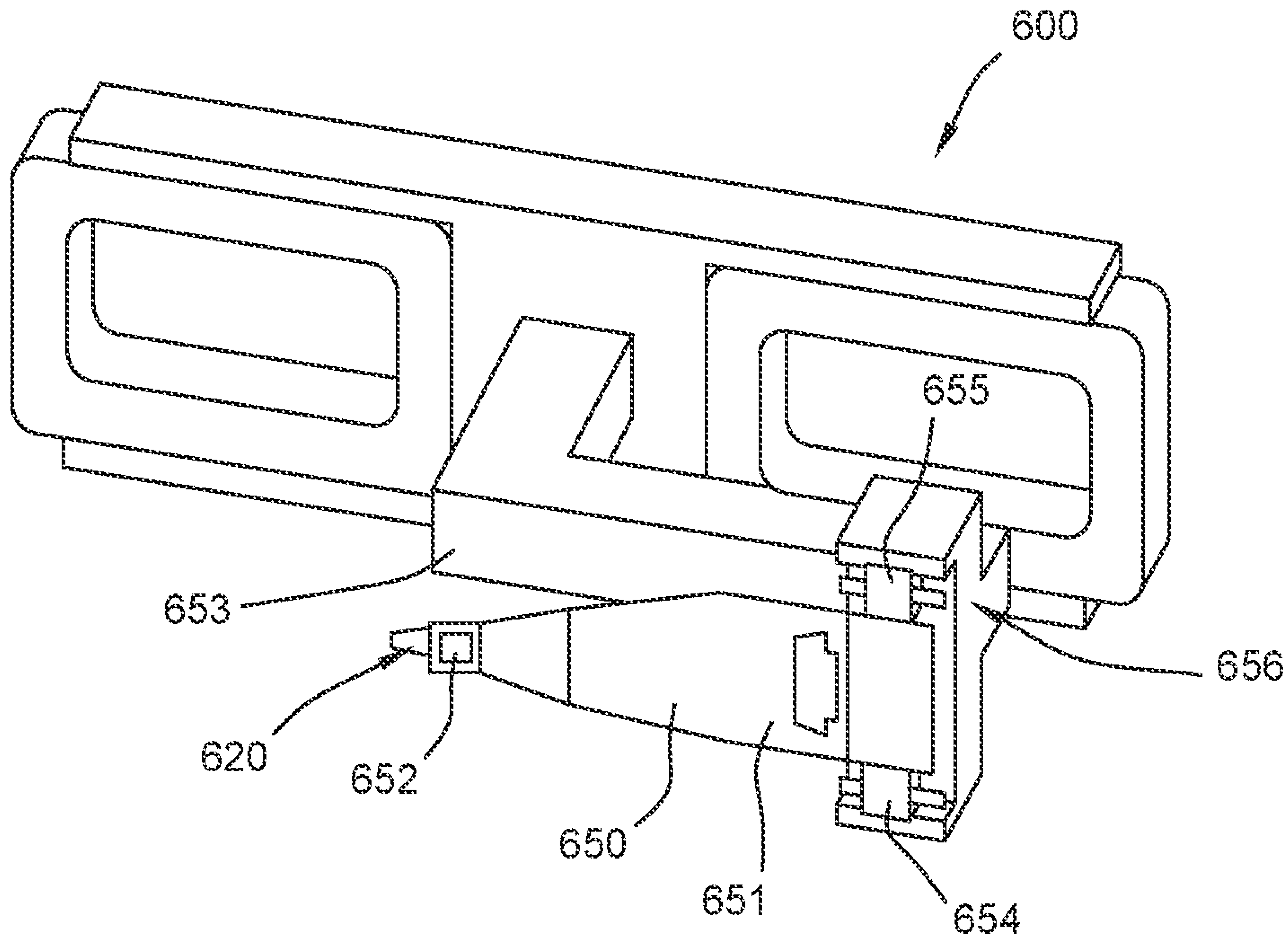

FIG. 6A

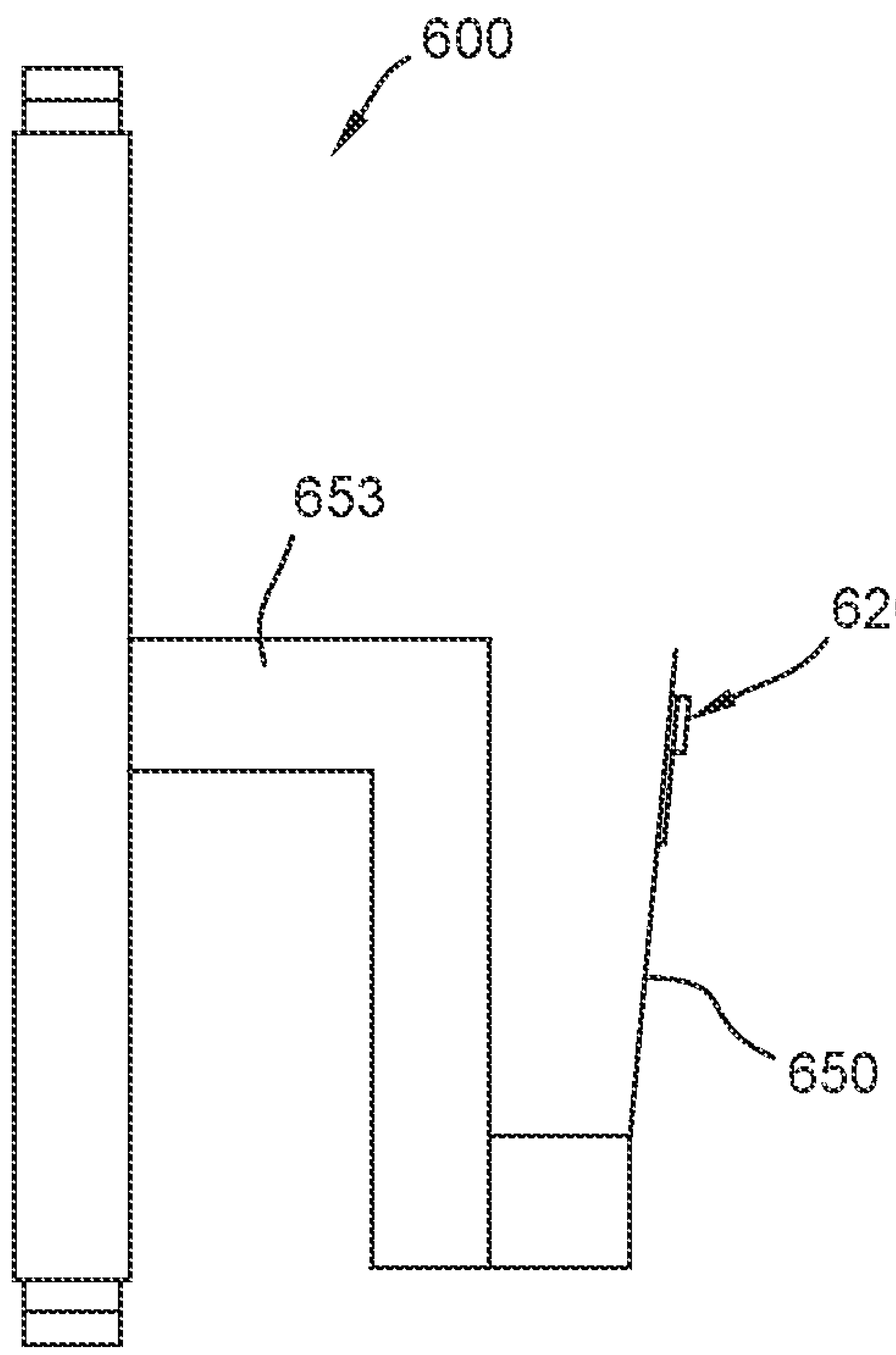

FIG. 6B

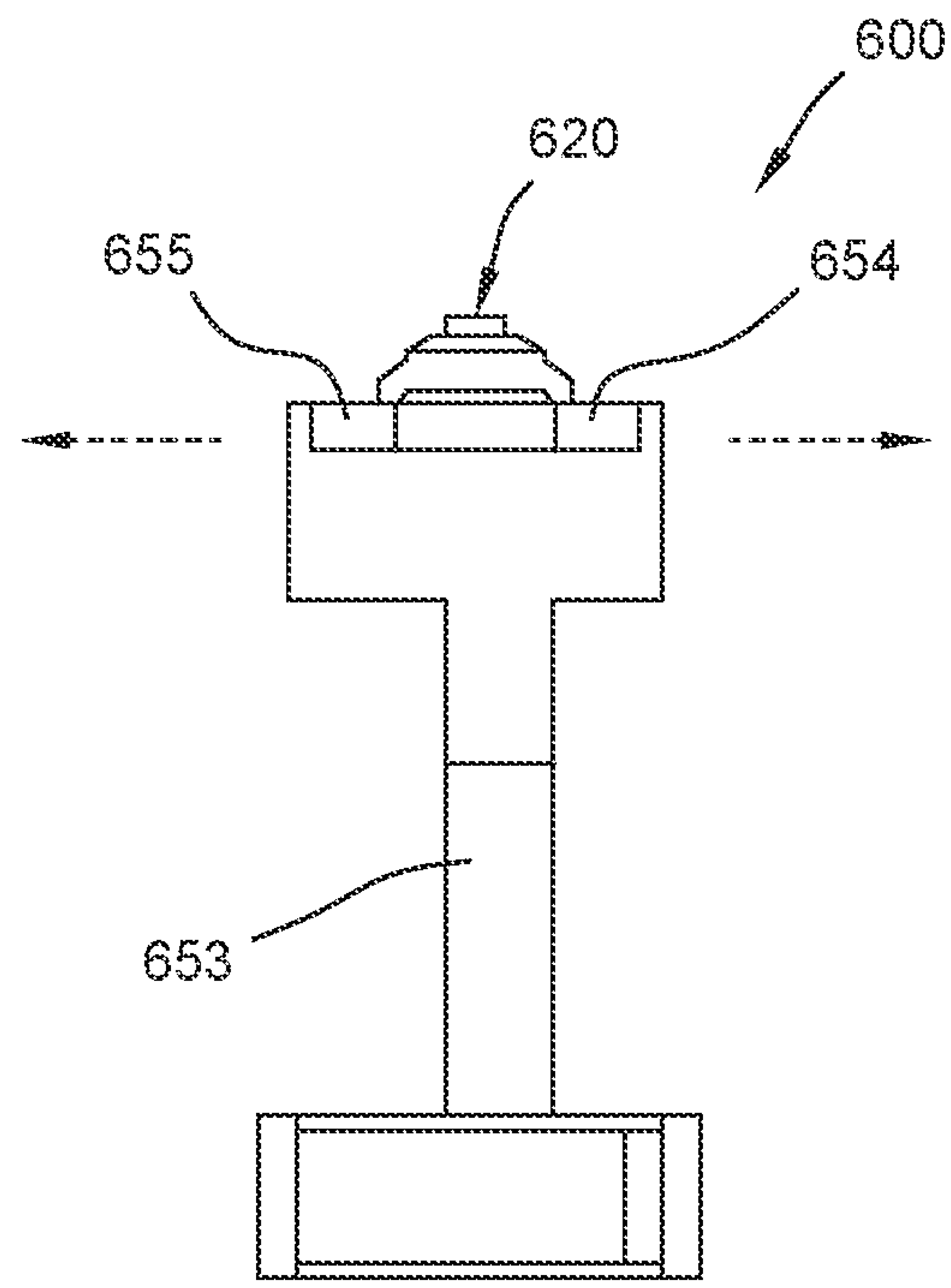

FIG. 6C

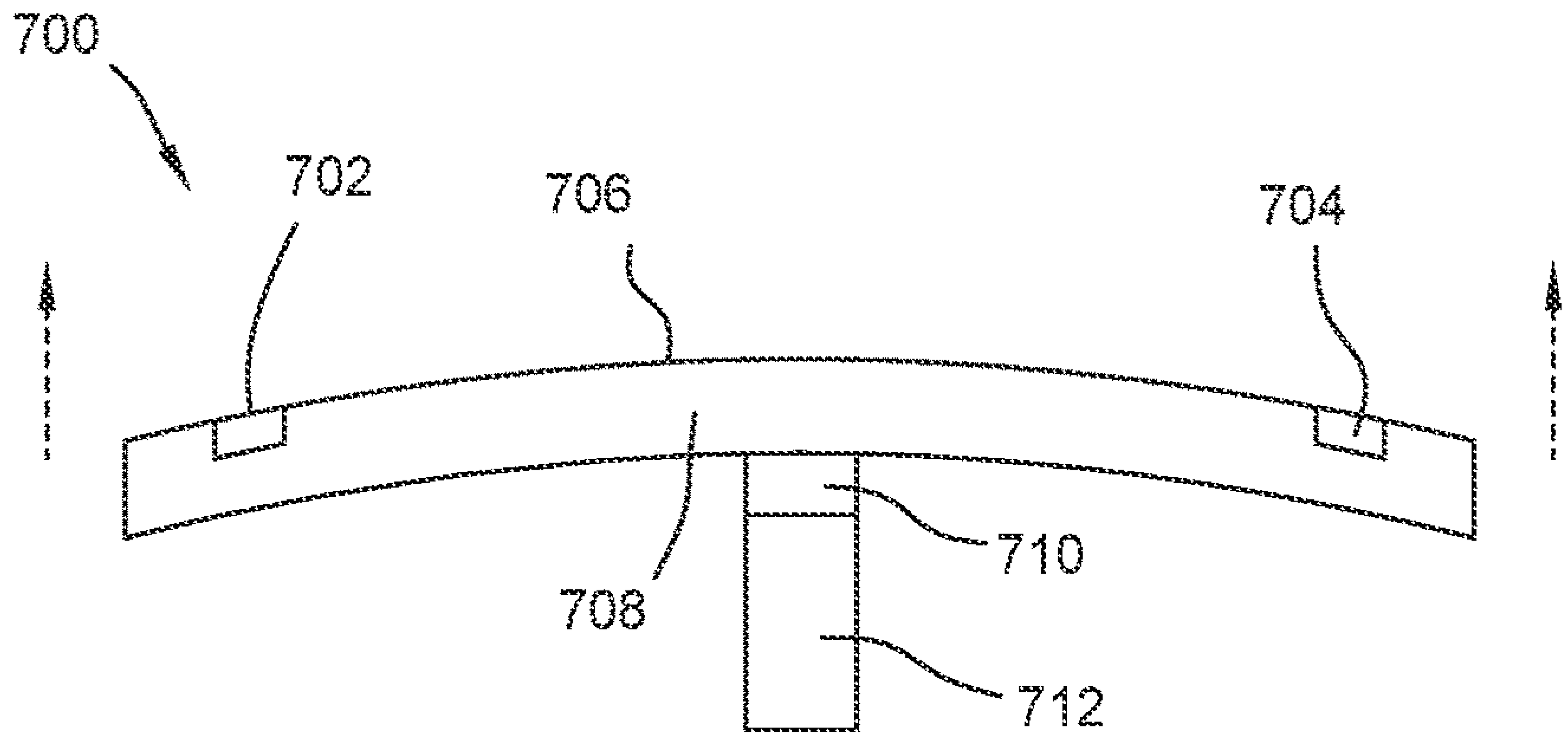

FIG. 7A

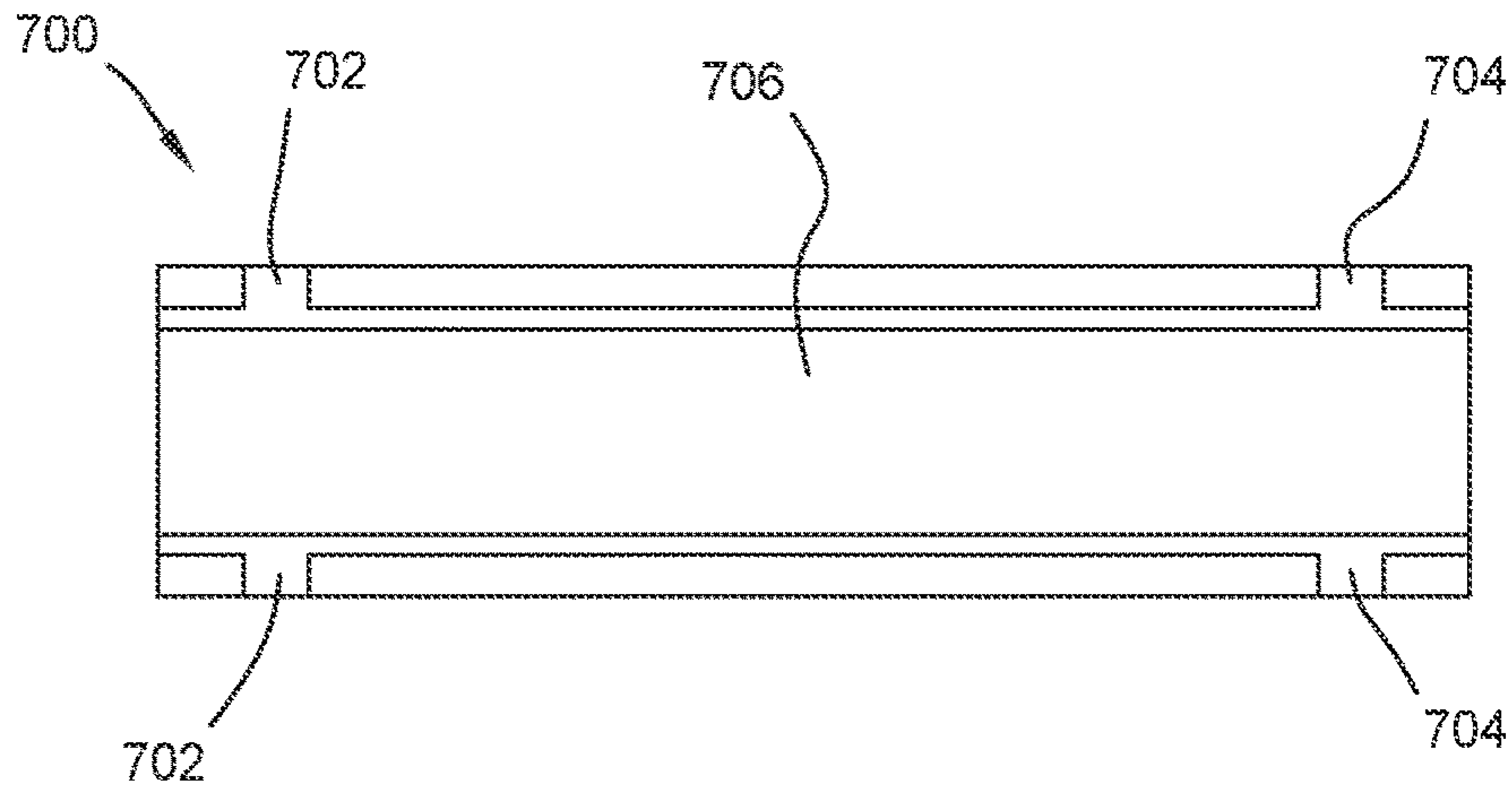

FIG. 7B

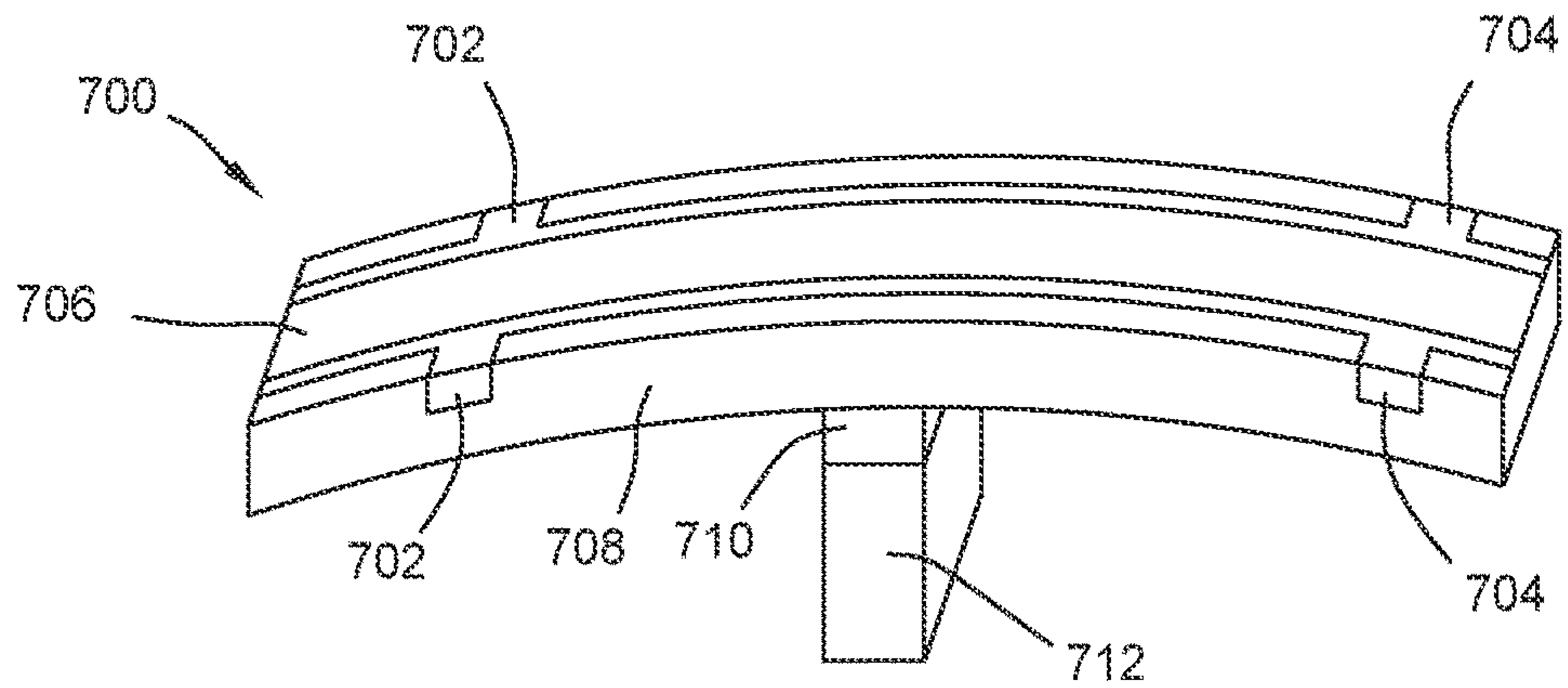

FIG. 7C

TAPE DRIVE WITH HEAD-GIMBAL ASSEMBLY AND CONTACT PLATE

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is a divisional of U.S. patent application Ser. No. 17/230,654, filed Apr. 14, 2021, which is a continuation of U.S. patent application Ser. No. 16/864,050, filed Apr. 30, 2020, now issued as U.S. Pat. No. 11,087,786, both of which are herein incorporated by reference.

BACKGROUND OF THE DISCLOSURE

Field of the Disclosure

Embodiments of the present disclosure generally relate to a tape embedded drive having a head-gimbal assembly (HGA) and a contact plate.

Description of the Related Art

Tape data storage is a system for storing digital information on magnetic tape using digital recording. Tape storage media is more commonly packaged in cartridges and cassettes. A tape drive performs writing or reading of data in the cartridges or cassettes. A common cassette-based format is linear tape open (LTO), which comes in a variety of densities.

Tape drives operate by using a tape head to record and read back information from tapes by magnetic processes. The tape head comprises servo elements and data elements that are arranged in an array that is oftentimes referred to as a tape head array.

In operation, the tape drive system uses an up/down stepping motor and voice coil motor (VCM), called dual stage motors, to move a large writer and reader head bar. The tape may stretch and move and thus not properly align with the tape head during read and/or write operations. Furthermore, the track spacing between adjacent data tracks can be different due to the stretching and/or moving of the tape.

Therefore, there is a need in the art for an improved tape drive that can correct tape stretching or movement.

SUMMARY OF THE DISCLOSURE

The present disclosure generally relates to a tape embedded drive having a head-gimbal assembly (HGA) and a contact plate. By using a support structure or contact plate beneath the tape, read and write heads can be designed to be narrower than the tape. The support structure or contact plate can stretch or relax the tape so that the spacing between servo tracks on the tape corresponds to the servo to servo spacing on the head. HGAs, which are narrower than the tape, can fly over the tape and read data from and write data to the tape. The HGA can have a single head or multiple heads. Additionally, multiple independent head assemblies can also be used for reading from and writing to the same tape.

In one embodiment, a storage device comprises: a first tape reel for unwinding tape media for storing data; a second tape reel for winding the tape media for storing data; a head assembly for reading data from and writing data to the tape media; and a contact plate movable from a first position spaced from the tape media to a second position in contact with the tape media, wherein the tape media is movable from a third position that is spaced a first distance from the head

assembly and a fourth position that is spaced a second distance from the head assembly, wherein the second distance is less than the first distance.

In another embodiment, a storage device comprises: a head-gimbal assembly for reading data from and writing data to the tape media, wherein the head-gimbal assembly is configured to fly above the tape media when reading data from and writing data to the tape media.

In another embodiment, a storage device comprises: a first tape reel for unwinding tape media for storing data; a second tape reel for winding the tape media for storing data; means to read data from and write data to the tape media, wherein the means to read data from and write data to the tape media is movable from a first position spaced a first distance from the tape media to a second position spaced a second distance from the tape media, wherein the means to read data from and write data to the tape media reads data from and writes data to the tape media at the second position; and means to move the tape media closer to and farther from the means to read data from and write data to the tape media.

BRIEF DESCRIPTION OF THE DRAWINGS

So that the manner in which the above recited features of the present disclosure can be understood in detail, a more particular description of the disclosure, briefly summarized above, may be had by reference to embodiments, some of which are illustrated in the appended drawings. It is to be noted, however, that the appended drawings illustrate only typical embodiments of this disclosure and are therefore not to be considered limiting of its scope, for the disclosure may admit to other equally effective embodiments.

FIGS. **1**A-**1**C are schematic illustrations of a tape embedded drive, according to various embodiments.

FIG. **2** is a schematic illustration of a Printed Circuit Board Assembly (PCBA), according to one embodiment.

FIG. **3** is a schematic illustration of a head assembly of a tape embedded drive, according to one embodiment.

FIGS. **4**A and **4**B are schematic illustration of a linear tape-open (LTO) head bar and a head bar for the tape embedded drive, according to one embodiment.

FIGS. **5**A-**5**B are schematic illustrations of a head assembly using a push-pull suspension system, according to various embodiments.

FIGS. **6**A-**6**C are schematic illustrations of a head assembly comprising a head gimbal assembly (HGA), according to various embodiments.

FIGS. **7**A-**7**C are schematic illustrations of a contact plate, according to various embodiments.

To facilitate understanding, identical reference numerals have been used, where possible, to designate identical elements that are common to the figures. It is contemplated that elements disclosed in one embodiment may be beneficially utilized on other embodiments without specific recitation.

DETAILED DESCRIPTION

In the following, reference is made to embodiments of the disclosure. However, it should be understood that the disclosure is not limited to specific described embodiments. Instead, any combination of the following features and elements, whether related to different embodiments or not, is contemplated to implement and practice the disclosure. Furthermore, although embodiments of the disclosure may achieve advantages over other possible solutions and/or over the prior art, whether or not a particular advantage is achieved by a given embodiment is not limiting of the disclosure. Thus, the following aspects, features, embodiments and advantages are merely illustrative and are not considered elements or limitations of the appended claims except where explicitly recited in a claim(s). Likewise, reference to "the disclosure" shall not be construed as a generalization of any inventive subject matter disclosed herein and shall not be considered to be an element or limitation of the appended claims except where explicitly recited in a claim(s).

The present disclosure generally relates to a tape embedded drive having a head-gimbal assembly (HGA) and a contact plate. By using a support structure or contact plate beneath the tape, read and write heads can be designed to be narrower than the tape. The support structure or contact plate can stretch or relax the tape so that the spacing between servo tracks on the tape corresponds to the servo to servo spacing on the head. HGAs, which are narrower than the tape, can fly over the tape and read data from and write data to the tape. The HGA can have a single head or multiple heads. Additionally, multiple independent head assemblies can also be used for reading from and writing to the same tape.

FIGS. **1A-1C** are schematic illustrations of a tape embedded drive **100**, according to various embodiments. The tape embedded drive, in FIGS. **1A** and **1B**, comprises a casing **105**, one or more tape reels **110**, tape media **115**, one or more motors (e.g., a stepping motor **120** (i.e., a stepper motor), a voice coil motor (VCM) **125**, etc.), a head assembly **130** with one or more read and write heads, a contact plate **160**, and tape guides/rollers **135***a*, **135***b*. The tape media **115** may be referred to as tape media **115** for exemplary purposes. In FIG. **1C**, the printed circuit board assembly (PCBA) **155** is mounted on an external surface of the casing.

In FIG. **1B**, two tape reels **110** are placed in the interior cavity of the casing **105**, with the center of the two tape reels **110** in-line with one another and on the same level in the cavity and with the head assembly **130** located in the middle and below of the two tape reels **110**. Tape reel motors **140** located in the spindles of the tape reels can operate to wind and unwind the tape media **115** in the tape reels. Each tape reel **110** may also incorporate a tape folder to ensure the tape media **115** is wound neatly onto the reel **110**. The tape media **115** may be made via a sputtering process to provide improved areal density.

Tape media **115** from the tape reels **110** are biased against the guides/rollers **135***a*, **135***b*, collectively referred to as guides/rollers **135**, with the two guides/rollers **135***a* furthest away from the head assembly **130** serving to change the direction of the film and the two guides/rollers **135***b* closest to the head assembly **130** pressing the tape media **115** towards the head assembly **130**.

As illustrated in FIG. **1A**, the guides/rollers **135** on the same side (i.e., left or right of the center axis of the long edge of the device) utilize the same structure. In FIG. **1B**, the guides/rollers **135** may have more specialized shapes and differ from each other based on function. The number of guides/rollers **135** illustrated in FIGS. **1A** and **1B** are not intended to be limiting, and a greater or a lesser number of rollers may be used in other embodiments. For example, the two function rollers may be cylindrical in shape, while the two functional guides may be flat-sided (e.g., rectangular prism) or clip shaped with two prongs and the film moving between the prongs of the clip.

The VCM **125** and the stepping motor **120** may variably position the one or more read/write tape heads transversely with respect to the width of the tape media **115**. The stepping motor **120** may provide coarse movement of the one or more read/write tape heads while the VCM **125** may provide finer actuation of the one or more read/write tape heads. In one embodiment, servo data can be written to the tape to aid in more accurate positioning of the one or more write/read heads along the tape film.

The contact plate **160** may comprise various mechanics to provide support to the backside (i.e., opposite of the writing side) of the tape media **115** when writing to or reading from the tape media **115**. By utilizing the contact plate **160** to support the backside of the tape media **115**, the less tension may be applied to the tape media **115**, thus lengthening the lifespan of the tape media **115**.

In FIG. **1A**, the casing **105** comprises one or more particle filters **141** and/or desiccants **142** to help maintain the environment in the casing. For example, if the casing is not airtight, the particle filters **141** and/or desiccants **142** may be placed where airflow is expected. The particle filters **141** and/or desiccants **142** may be placed in one or more corners or in one or more locations away from the moving internal components. For example the moving reels **110** may generate internal airflow as the tape media **115** winds/unwinds, and the particle filters **141** and/or desiccants **142** may be placed within the generated internal airflow.

The placement of the internal components within the casing **105** of the tape embedded drive **100** may be different according to various embodiments. For example, in one embodiment, the head assembly **130** is internal to the casing **105**, such that the tape media **115** is not exposed outside of the casing **105**, such as in conventional tape drives. Thus, the tape film does not need to be routed along the edge of the casing and can be freely routed in more compact or otherwise more efficient ways within the casing. The one or more read/write tape heads and tape reels **110** may be placed in a variety of locations to achieve a more efficient layout, as there is no design requirement to provide external access to the previously mentioned components.

In FIG. **1C**, the casing **105** comprises a cover **150** and a base **145**.

The PCBA **155** is attached to the bottom of the external surface of the casing **105** and opposite of the cover **150**. Since the PCBA **155** is made of solid state electronics and may be more durable to the environment, the PCBA **155** does not need to be placed inside the casing **105**. However, in some embodiments, the PCBA **155** is placed inside the casing **105**. The placement of the PCBA **155** on the outside of the casing **105** releases space within the cavity of the tape embedded drive **100** that would otherwise be occupied by the PCBA **155**. The space released by the placement of the PCBA **155** may be utilized to place other components, such as filters **141** and/or desiccants **142** to better protect to the internal environment of the tape embedded drive **100**.

FIG. **2** is a schematic illustration of a Printed Circuit Board Assembly (PCBA), according to one embodiment. The PCBA **155** is attached to the bottom surface of the casing, with a connector **205** attaching to contacts or an interface on the bottom surface electrically/electronically connected to internal components in the casing. For example, the contacts or the interface may be electronically connected to one or more motors, such as the VCM **125** and the stepping motor **120** of FIG. **1**, and/or actuators within the casing, such as the casing **105** of FIG. **1**. In one embodiment, the contacts/interface are built into the casing **105** without comprising the hermetically sealed casing **105**. In another embodiment, the connector **205** can be electrical feed-through electrically connecting components inside the casing **105** to those on the PCBA **155**, while maintaining the hermetic seal of the casing **105**.

The PCBA **155** comprises various components, such as one or more controllers, one or more connectors **205**, system on chip (SoC) **210**, one or more data interfaces **215** (e.g., Serial ATA (SATA), Serial attached SCSI (SAS), non-volatile memory express (NVMe), or the like), memory **220**, Power Large Scale Integration (PLSI) **225**, and/or data read channel controller **230**. One or more cutouts **235** may be added to the PCBA **155** to provide additional space for tape reel motors, such as the tape reel motors **140** of FIG. **1**. For example, the portion of the casing **105** above the tape reel motors **140** may be raised to provide additional space for the motors. The cutouts **235** may allow for the reduction of the thickness of the tape embedded drive **100** as the PCBA **155** may surround the raised portion of the casing **105**.

The PCBA **155** may extend along the entire bottom exterior surface of the casing **105** or may only partially extend along the surface, depending on the space requirements of the various tape embedded drive components. In some embodiments, a second PCBA (not shown) may be located internally in the casing **105** and be in communication with the first PCBA **155**, for example, via the connector **205**.

In various embodiments, a controller on the PCBA **155** controls the read and write operations of the tape embedded drive **100**. The controller may engage the tape reel motors **140** and cause the tape reels **110** to wind the tape media **115** forwards or backwards. The controller may further use the VCM and the stepping motor, such as the VCM **125** and the stepping motor **120** of FIG. **1**, to control the placement of the one or more read/write tape heads above the tape media **115**. The controller may also control the input/output of data to or from the tape embedded drive **100** through one or more interfaces **215**, such as SATA or SAS.

FIG. **3** is a schematic illustration of a head assembly **300** of a tape embedded drive **100**, according to one embodiment. The head assembly **300** comprises a multi-stage actuator for moving the head assembly **300**. In some embodiments, the multi-stage actuator comprises a stepping motor **305** (first stage), which may provide coarse actuation, a voice coil motor **310** (second stage) comprising a coil **329** and magnet **330**, which may provide fine actuation, and a piezoelectric actuator **315** (third stage), which may provide ultra-fine actuation for up/down movement of a head bar **320**. In one embodiment, the piezoelectric actuator **315** is a lead zirconate titanate (PZT) actuator (e.g., shear PZT). By using a 3-stage motor, the movement of the head bar **320** can be more precise. With greater precision, more channels can be supported on the tape film, potentially allowing for greater data density on the tape media **115**. In one embodiment, the head bar **320** comprises heads in a write-read-write layout, similar in layout to conventional tape heads. In another embodiment, the head bar **320** comprises two heads in a read-write layout, similar in layout to HDD heads.

The head assembly **300** further comprises a screw shaft **325** coupling an actuator block **326** to the stepping motor **305**. The screw shaft **325** and guide shafts **324**, **340** may facilitate movement of the actuator block by the stepping motor **305**. In some embodiments, a different number of guide shafts **324**, **340** are used (e.g., 0, 1, 3+). For example, smaller or lighter actuator blocks may need less support during movement and use only one or even no guide shafts. Meanwhile, larger or heavier actuator blocks may use additional guide shafts or multiple screw shafts.

A suspension assembly **328** couples the head bar **320** to the actuator block **326**. In one embodiment, the suspension assembly **328** comprises a mounting plate, a load beam, and a laminated flexure to carry the electrical signals to and from the read and write heads in the head bar **320**. The suspension assembly **328** comprising a coil **329** through which a controlled electrical current is passed. The coil **329** interacts with one or more magnets **330** attached to the actuator block **326** to form a voice coil motor **310** to controllably move the head bar **320**.

In one embodiment, a head support block **335** couples the head bar **320** and piezoelectric actuator **315** to the suspension assembly **328**. The head support block **335** comprises a clamp **336** to secure the head bar **320** and the piezoelectric actuator **315** to a supporting structure **337** perpendicular to the clamp **336** to couple the base to the suspension assembly **328**. In another embodiment, the head support block **335** and the actuator **315** form a suspension system that allows the head bar **320** to move across the width of the tape media **115**, in conjunction with the control provided by the VCM **310** and the stepping motor **305**.

In one embodiment, the piezoelectric actuator **315** may optionally be a multilayer piezoelectric element, comprising a plurality of piezoelectric material layers sandwiched between conductive (e.g., gold) electrode layers. In another embodiment, the piezoelectric actuator **315** may optionally comprise one or more of the many known piezoelectric materials, such as lead zirconate titanate, lead scandium tantalite, lanthanum gallium silicate, lithium tantalite, barium titanate, gallium phosphate, and/or potassium sodium tartrate.

In one embodiment, the piezoelectric actuator **315** extends or contracts along a second axis. The actuator **315** may push the head bar **320** towards the tape media **115** or pull the head(s) away from the tape media **115**. In one embodiment, a heater (e.g., heating coil) may be incorporated into the head bar **320** in order to cause the one or more read/write heads to move closer to the tape film. A touchdown sensor may also be incorporated into the head bar **320** to detect head-film contact and prevent the head bar from touching the tape media **115**.

By allowing the one or more read/write heads to move closer to the tape film, the signal strength can be increased. In addition, by allowing the head bar **320** to move away from the tape media **115**, a fast-forward or fast-rewind function may be enabled for the tape embedded drive **100**. As the head bar **320** is further away from the media, the chances of the media hitting the head bar is decreased even if the tape media **115** is moving faster. By avoiding contact, the reliability of the read/write heads and/or the tape media **115** is maintained.

In order to better secure the head assembly **300** to the casing **105**, a second guide shaft **340** may be used. In one embodiment, the first guide shaft **324** is on one side of the actuator block **326** with the second guide shaft **340** on the opposite end of the actuator block **326**.

In one implementation, movement of the head bar **320** is accomplished in a 3-stage action. First, the stepping motor **305** rotates the screw shaft **325**, causing the actuator block **326** to move up and down the first guide shaft **324** and the second guide shaft **340**. The head bar **320** moves across (i.e., up and down) the width of a tape media **115**. When a current is applied to the VCM coil, the head support block **335** moves in the similar fashion (i.e., up and down the width of the tape media **115**) as the head bar **320**, while being supported by the suspension assembly **328**. When a voltage is applied to the piezoelectric actuator **315**, the one or more read/write heads move across (i.e., up and down) the width of the tape media **115**. Working in tandem, the 3-stage action can move the head bar **320** across (i.e., up and down) the width of the tape film in coarse, fine, or ultra-fine increments. In one embodiment, the 3 stages of movement proceed at around a **30,000/10,000/1** ratio, with the stepping motor **305** capable of moving up to about 12.65 mm, the VCM **310** capable of moving up to about 4 mm, and the piezoelectric actuator **315** capable of moving up to about 0.4 μm.

FIG. **4**A is a schematic illustration of a linear tape-open (LTO) head bar **405** and a head bar **410** for the tape embedded drive, according to one embodiment. LTO cassettes comprise a stepping motor, such as the stepping motor **120** of FIG. **1** or the stepping motor **305** of FIG. **3**, and a VCM, such as the VCM **125** of FIG. **1** or the VCM **310** of FIG. **3**, to actuate the head bar **410**. In one embodiment, FIG. **4**A illustrates the relationship between tape width and tape head bar length for LTO.

Multiple writers and readers may be located in a head bar. For example, a tape bar may have 1-10 reader heads and/or 1-10 writer heads. Typically, a tape head bar uses a writer-reader-writer layout. However, other layouts, such as writer-reader-reader-writer may be used. In various embodiments, using two or more readers provides better signal-to-noise ratio (SNR), allowing for higher TPI.

Tape recording uses head film contact technology for recording. Typically, an LTO tape uses four data bands on the film, in which the one or more read/write heads are moved to four different locations up and down the width of the tape. The stepping motor is used to move the head bar to each of the four locations, with the voice coil motor handling finer actuation within each location. Thus, an LTO cassette uses a longer head bar length (e.g. 22.4 mm) than the tape width (e.g. 12.65 mm), so that the tape width is covered by the head bar in each of the four possible locations that the stepping motor may move the head bar.

Due to the heavy mass of the longer head bar **405**, wider head reader width and limited movement granularity of the stepping and voice coil motors, the track density on the film for an LTO cassette is limited. An LTO-7 track pitch is about 10.7 k TPI (2.37 um).

In one embodiment, the tape embedded drive **100** comprises a significantly smaller head bar **410** than an LTO head bar **405**, such as a head bar **410** of about 4 mm in length. With a shorter head bar length and corresponding less mass, the head bar can be moved up and down by PZT ultra-fine actuation. In one embodiment, the head assembly, such as the head assembly **130** of FIG. **1** or the head assembly **300** of FIG. **3**, is attached to the PZT actuator, such as the PZT actuator **315** illustrated in FIG. **3**, which is located on an assembly attached to an actuating portion of the voice coil motor, which in turn is on an assembly attached to an actuating portion of the stepping motor. In one embodiment, the PZT actuator **315** is moved by the VCM and the VCM is in turn moved by the stepping motor.

While the above discusses head bar sizes of about 4 mm, other sizes are possible, such as about 3 mm, about 5 mm, or even other sizes. In some embodiments, the head bar is significantly smaller than the tape width. For example, the head bar may be less than half or even less than a quarter of the width of the tape media.

In one embodiment shown in FIG. **4**B, two tape guides **415** are located on both sides of the tape assembly. The tape guides **415** limit the movement of the tape media, such as the tape media **115** of FIG. **1**, and provide better stability when the head assembly is moving over the tape media **115**. In another embodiment, a single tape guide placed either before or after the head assembly may be utilized.

The head bar **410** may be supported by an HDD-like gimbal assembly or suspension assembly, such as the gimbal assembly illustrated in FIG. **3**. The assembly may provide gentler and/or more stable head to film contact, potentially providing better reliability for reading and/or writing. The suspension assembly may use a variety of materials, such as stainless steel or the like.

FIGS. **5**A-**5**B are schematic illustrations of a head assembly **500** using a push-pull suspension system, according to various embodiments. Push-pull actuators generally use less voltage than shear actuators. The push-pull suspension system comprises a push actuator **541**, a pull actuator **542**, and a frame **543**. In one embodiment, the push actuator **541**, the pull actuator **542**, and a plurality of suspension wires connect the head bar **520** to the frame **543** connected to a support structure **544**.

Working in tandem, the push actuator **541** and pull actuators **542** may move the suspended head bar **520** up and down relative to the width of the tape, as illustrated by the dashed arrows in FIG. **5**B. For example, when the push actuator **541** contracts, the pull actuator **542** expands, thereby pushing the head bar **520** to one direction (up). When the push actuator **541** expands and the pull actuator **542** contracts, the head bar **520** is pushed in the opposite direction (down). In one embodiment, the push actuator **541** and pull actuator **542** are PZTs.

The suspension system can also comprise wire suspensions **545***a*, **545***b* for movably supporting the one or more read/write heads. In one embodiment, the wire suspensions **545***a*, **545***b* are made of a flexible material that can be easily moved by the push actuator **541** and pull actuator **542**. In the illustrated embodiment, two suspension wires are placed on each side of the one or more read/write heads.

The design of the wire suspensions may be different to account for the desired movement of the head bar **520**. For example, the push/pull actuators **541**, **542** are moving the head bar **520** across the width of the tape media, such as the tape media **115** of FIG. **1**, as illustrated by the dashed arrows. In one embodiment, a first wire suspension type **545***a* is configured to facilitate the up-down movement, for example, by having a loop section configured to compress along the up-down movement. In one embodiment, a second wire suspension type **545***b* is configured to reduce lateral movement during the up-down movement. For example, the second suspension wire may be stiffer, utilize a higher tensile material, and/or utilize a shape (e.g., a “W” shape) that reduces compression along the direction perpendicular to the up-down motion. In one embodiment, the push-pull actuator designs used in HDDs may be adapted for use in the tape embedded drives **100**, as described above, due the high reliability and low production cost of the push-pull actuator designs.

FIGS. **6**A-**6**C are schematic illustrations of a head assembly **600** comprising a head gimbal assembly (HGA) **650** adapted from HDD HGAs, according to various embodiments. FIG. **6**C is a side profile view of FIG. **6**B rotated 90 degrees along an axis. The HGA **650** comprises an elongated suspension **651** comprising a top end and a base end. The suspension **651** may support, on its top end, one or more heads **620** and one or more head sliders with an air bearing system **652**.

The elongated suspension **651** may be connected, at its base end, to a supporting structure **653** by one or more actuators **654**, **655** and a spring-type clamp **656**. In the illustrated embodiment, the one or more actuators **654**, **655** are a push-pull actuator, with a first actuator **654** and a second actuator **655** connecting the base of the suspension

651 to the spring-type clamp 656 that connects the suspension 651 to the supporting structure 653.

In an embodiment, the first actuator 654 and the second actuator 655 are PZT actuators. As shown in FIG. 6C, when the first actuator 654 expands and the second actuator 655 contracts, the one or more read/write heads move to the left. When the first actuator 654 contracts and the second actuator 655 expands, the head(s) move to the right.

FIGS. 7A-7C are schematic illustrations of a contact plate 700, according to various embodiments. The contact plate 700 may be the contact plate 160 of FIG. 1A and FIG. 1B. The contact plate 700 provides support to the backside of the tape media, such as the tape media 115 of FIG. 1, when a head, such as a flying head or a HDD HGA as illustrated in FIGS. 6A-6C. The term "flying head" may be used interchangeably with HDD HGA for exemplary purposes. The contact plate 700 comprises several elements, such as a first actuator 702 and a second actuator 704 working in tandem, a contact plate 706 of a contact plate structure 708, a base 712 of the contact plate structure 708, and a base mechanical component 710.

The contact plate structure 708 may be formed with any suitable material to provide support to the tape media 115 and the flying head. In one embodiment, the contact plate structure 708 is a flat structure. In another embodiment, the contact plate structure 708 is a curved structure. In yet another embodiment, the contact plate structure 708 is any suitable shape to provide support to the flying head and the tape media 115. The contact plate structure may be moved towards or away from the flying head to provide the appropriate amount of support to the flying head during read/write operations by a base mechanical component 710. The base mechanical component 710 may be an additional feature of the base 712 to maneuver the contact plate structure into an appropriate position.

The contact plate 706 may be coated in a material suitable to reduce and minimize friction as the tape media 115 moves across the surface of the contact plate 706 during a read and/or write operation. In one embodiment, the contact plate 706 width may be a similar size to the tape media described in FIG. 4A. In another embodiment, the contact plate 706 may be wider than the tape media described in FIG. 4A. In yet another embodiment, the contact plate track 706 has a leading edge taper and a trailing edge taper to allow for adjustment. In one embodiment, the contact plate 706 comprises elements to manipulate the tape media 115, such as a heating element. In another embodiment, the contact plate 706 comprises elements to maneuver the tape media 115, such as a tape guide, like the tape guide 615 described in FIG. 4A.

In one embodiment, the first actuator 702 and the second actuator 704 are PZT actuators. Illustrated in FIG. 7A and FIG. 7B, when the first actuator 702 expands and the second actuator 704 contracts, the contact plate 706 tilts in the direction of the second actuator 704. Likewise, when the second actuator 704 expands and the first actuator 702 contracts, the contact plate 706 tilts downwards in the direction of the first actuator 702. The tilting of the contact plate 706 allows for the tension or pressure to be applied to the tape media 115 to provide support for the flying head or the HDD HGA when reading from or writing form the tape media 115.

By using a contact plate as well as a head-gimbal assembly, tape media can be properly read without worry of tape stretching or movement.

It is to be understood that while embodiments discussed herein make reference to a tape drive having two reels, it is contemplated that tape drives having a single reel, along with a contact plate, may be used as well. For example, a read/write head, along with a contact plate, may be disposed in a cartridge or enclosure that may then be inserted into a device. Additionally, the cartridge may have one or two reels disclosed therein. The cartridge is contemplated to be insertable into a device for use.

In one embodiment, a storage device comprises: a first tape reel for unwinding tape media for storing data; a second tape reel for winding the tape media for storing data; a head assembly for reading data from and writing data to the tape media; and a contact plate movable from a first position spaced from the tape media to a second position in contact with the tape media, wherein the tape media is movable from a third position that is spaced a first distance from the head assembly and a fourth position that is spaced a second distance from the head assembly, wherein the second distance is less than the first distance. The head assembly is spaced from the tape media when reading data from and writing data to the tape media. The head assembly is a head-gimbal assembly. The contact plate has a curved surface for contacting the tape media. The contact plate is movable to maintain the second distance as a substantially constant distance while the tape media is moving. The contact plate comprises a piezoelectric material. The storage device includes an enclosure and wherein the first tape reel, the second tape reel, the head assembly, and the contact plate are all disposed within the enclosure.

In another embodiment, a storage device comprises: a head-gimbal assembly for reading data from and writing data to the tape media, wherein the head-gimbal assembly is configured to fly above the tape media when reading data from and writing data to the tape media. The head-gimbal assembly is movable from across the tape media in a direction perpendicular to a direction that the tape media moves during operation. The head-gimbal assembly includes a slider and a magnetic head assembly coupled thereto. The storage device further comprises a suspension coupled to the slider. The storage device further comprises an actuator arm coupled to the slider. The storage device further comprises a voice coil motor coupled to the actuator arm. The storage device further comprises a contact plate, wherein the tape media is configured to move across the contact plate during device operation.

In another embodiment, a storage device comprises: a first tape reel for unwinding tape media for storing data; a second tape reel for winding the tape media for storing data; means to read data from and write data to the tape media, wherein the means to read data from and write data to the tape media is movable from a first position spaced a first distance from the tape media to a second position spaced a second distance from the tape media, wherein the means to read data from and write data to the tape media reads data from and writes data to the tape media at the second position; and means to move the tape media closer to and farther from the means to read data from and write data to the tape media. Both the first position and the second position are spaced from the tape media. The means to move the tape media contacts the tape media. The storage device further comprises means to stretch the tape media. The storage device further comprises an enclosure and wherein the means to read data from and write data to the tape media and the means to move the tape media are disposed within the enclosure. The storage device further comprises means to correct track spacing on the tape media.

While the foregoing is directed to embodiments of the present disclosure, other and further embodiments of the disclosure may be devised without departing from the basic scope thereof, and the scope thereof is determined by the claims that follow.

What is claimed is:

1. A storage device, comprising:
a tape reel;
a tape media coupled to the tape reel; and
a head-gimbal assembly for reading data from and writing data to the tape media, wherein the head-gimbal assembly is configured to fly above the tape media when reading data from and writing data to the tape media and wherein the head-gimbal assembly comprises:
a suspension having a base end, a top end, and a longitudinal axis extending from the base end to the top end;
a slider coupled to the top end of the suspension;
a magnetic head assembly coupled to a top end of the slider;
a first actuator coupled to a first side of the base end of the suspension, the first side being disposed in a direction perpendicular to the longitudinal axis; and
a second actuator coupled to a second side of the base end of the suspension, the second side being opposite the first side, wherein the first and second actuators are piezoelectric push-pull actuators.

2. The storage device of claim **1**, further comprising a cartridge, wherein the tape reel, tape media, and head-gimbal assembly are disposed within the cartridge.

3. The storage device of claim **1**, wherein the slider is narrower in width than the tape media.

4. The storage device of claim **1**, further comprising a stepping motor coupled to the head-gimbal assembly.

5. The storage device of claim **1**, wherein the first and second actuators are configured to move the magnetic head assembly in a first direction parallel to a width of the tape media and in a second direction anti-parallel to the first direction.

6. The storage device of claim **1**, wherein the first actuator is configured to expand to move the suspension in a first direction, and wherein the second actuator is configured to expand to move the suspension in a second direction opposite the first direction.

7. A storage device, comprising:
a tape media; and
a head-gimbal assembly comprising:
a suspension having a top end, a base end, and a longitudinal axis extending from the base end to the top end;
a magnetic head assembly disposed on the top end of the suspension for reading data from and writing data to the tape media;
a first actuator coupled to a first side of the base end, the first side being disposed in a direction perpendicular to the longitudinal axis; and
a second actuator coupled to a second side of the base end opposite the first side, wherein the first and second actuators are configured to move the magnetic head assembly in a first direction and a second direction opposite the first direction, the first direction being parallel to a width of the tape media and the second direction being anti-parallel to the first direction, wherein the first and second actuators are piezoelectric push-pull actuators.

8. The storage device of claim **7**, wherein the head-gimbal assembly is configured to fly above the tape media when reading data from and writing data to the tape media.

9. The storage device of claim **7**, wherein the first direction is towards the first side of the base end of the suspension and the second direction is towards the second side of the base end of the suspension.

10. The storage device of claim **7**, further comprising a stepping motor coupled to the head-gimbal assembly, wherein the head-gimbal assembly further comprises a slider and an air bearing system disposed on the top end of the suspension.

11. The storage device of claim **7**, wherein the first and second actuators are each individually lead zirconate titanate (PZT) actuators.

12. The storage device of claim **7**, the suspension is coupled to a supporting structure by a spring-type clamp and the first and second actuators.

13. The storage device of claim **7**, further comprising a cartridge, wherein the tape media and the head-gimbal assembly are disposed within the cartridge.

14. A storage device, comprising:
a tape media; and
a head-gimbal assembly comprising:
an elongated suspension;
a slider disposed on a top end of the elongated suspension;
a magnetic head assembly disposed on the slider for reading data from and writing data to the tape media;
means for moving the magnetic head assembly in a first direction and a second direction opposite the first direction, wherein the slider is configured to fly above the tape media when reading data from and writing data to the tape media; and
means for moving the tape media closer to and farther from the magnetic head assembly.

15. The storage device of claim **14**, wherein the head-gimbal assembly further comprises means for coupling the elongated suspension to a supporting structure.

16. The storage device of claim **14**, wherein the means for moving the magnetic head assembly in the first direction and the second direction is coupled to a base end of the elongated suspension.

17. The storage device of claim **14**, further comprising a stepping motor coupled to the head-gimbal assembly.

18. The storage device of claim **14**, wherein the head-gimbal assembly further comprises an air bearing system disposed on the top end of the suspension, and wherein the magnetic head assembly is narrower in width than the tape media.

19. The storage device of claim **14**, wherein the first direction is parallel to a width of the tape media and the second direction is anti-parallel to the first direction.

20. The storage device of claim **14**, further comprising a cartridge, wherein the tape media and the head-gimbal assembly are disposed within the cartridge.

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